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TRIBOLOGICAL BEHAVIOUR FOR STIR CAST Al5086/Gr/Al_2O_3 HYBRID MATRIX COMPOSITE

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ABSTRACT

Aluminum Hybrid Reinforcement Technology is a reaction to the dynamic regularly expanding administration necessities of ventures, for example, Transportation, Aerospace, Automobile, Marine, and so forth since they are bendable, profoundly conductive, light weight and have a high quality to weight proportion. In this development, an endeavour has been made to research the wear rate of Al5086 hybrid metal matrix composite strengthened with the hard earthenware Alumina (4, 8, 12 wt. % of Al_2O_3) and delicate strong oil of graphite (2, 4, 6 wt. % of Gr) manufactured by utilizing mix throwing technique. The un-greased up pins on plate wear tests were directed to look at the wear conduct of Al5086/12 wt. % of Al_2O_3/Gr composites. The sliding wear tests were completed at different heaps of (15, 30, 45 N), sliding speed (1.25, 2.50, 3.25 m/sec), and diverse graphite wt. % (2, 4, 6 wt. %).

Keywords: Al5083; Al_2O_3; Graphite; Taguchi techniques; wear rate.

I. INTRODUCTION

Aluminum Hybrid Matrix Composites are becoming better substitutes for the conventional Aluminum Alloys because of the characteristics like improved strength to weight ratio, energy saving, better wear resistance etc [1]. Interest in particulate reinforced aluminum hybrid matrix composites for the use in the automotive industry and other structural applications has increased because of the physical and mechanical properties they possess [2]. Aluminum based hybrid matrix composites with a variety of particulate reinforcements such as Al_2O_3, TiC, Ti_2B, B_4C, TiN, Si_3N_4, graphite and industrial waste by- product have been conceived and developed for various potential applications [3]. Aluminum hybrid matrix composites are developed by the researchers and they are used in many commercial and industrial applications [4]. Newer compositions have been continuously explored and the related valuable studies presented by the past researchers are discussed. Veeresh Kumar et al [5] have conducted the experiment on Al6061/SiC and Al7075/Al_2O_3 metal matrix composites and present the experimental results of the studies regarding hardness, tensile strength and wear resistance properties of Al6061/SiC and Al7075/Al_2O_3 composites. The SiC and Al_2O_3 resulted in improving the hardness and density of their respective composites. Wang and Yan [6] investigated the feasibility of machining Al6061/Al_2O_3 composite materials by electro discharge machining for blind hole drilling and evaluated the material removal rate, tool wear rate and surface roughness with various input parameters. Yan and Wang [7] observed that material removal rate increased with peak current and was erratic with pulse duration. The material removal rate, tool wear rate and surface roughness increases with flushing pressure during machining of Al6061/Al_2O_3 composites using rotary electro discharge machining with a tube electrode. Yan et al [8] found that in case of rotary electro discharge machining process, the main challenge is of using a disk like electrode for machining Al6061/Al_2O_3 composites. Veeresh kumar et al [9] investigated the influence of reinforcement on mechanical properties when different matrix materials that is Al6061 and Al7075 and reinforcements such as SiC and Al_2O_3 are used and they observed micro hardness of the composite were increased with the increase of filler content.

While many researchers have carried out on the mechanical, wear properties and machining characteristics of aluminum metal matrix composites with graphite and Al_2O_3 as reinforcing materials. In the case of hybrid Al5086/Gr/Al_2O_3 composites, limited literatures is available, encompassing various aspects such as mechanical properties and wear behaviour and conduct the machining study of the composites. Aluminum based Al_2O_3 particle reinforced composite material have become useful engineering materials due to their properties such as low weight, heat resistant, wear resistant and low cost. These are found in various engineering applications such as cylinder block liners, vehicle drive shafts, automotive pistons, bicycle frames etc.

II. EXPERIMENTAL DETAILS

The stir casting technique is the simplest and the most economical process for producing particulate reinforced composites available for particulate reinforced metal

matrix composites. In this technique, in order to accomplish the optimum property of the hybrid composite, the distribution of the reinforced particles in the base material sought to be homogeneous and the wet ability among the olden materials and particulates ought to be optimized. The moisture level with cast composite must be minimized and the element reactions between the particle material and the base material have to be avoided. The whirlpool method is individual of the enhanced recognized approaches used to build a high quality allocation of the reinforced material in the base matrix. During this, once the base material is melted, it is stirred forcefully by automatic agitator to form a whirlpool at the face of liquefy, and the particle material is subsequently introduced at the region of the vortex.

A. *Material fabrication*

The chemical composition of Al5086 alloy is given in Table 1 and Al5086 alloy was melted in a crucible in a generation type of furnace at 725ºC. Subsequent to melting and degassing by nitrogen, an alumina coated stainless steel stirrer was meant for stirring at 600 rpm used for 20 min time duration. During stirring, it is preheated at 600ºC, particles alumina and MoS_2 powder was added. After that the composite alloy was roll poured into the pre heated (250ºC) permanent mould. The Al5086 alloy with different wt. % of hybrid composites is produced and test specimens were machined.

TABLE I
Chemical composition of Al5086 alloy

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.65	0.7	0.25	0.15	0.8	0.07	0.25	0.15	Remaining

B. *Mechanical behaviour*

The hardness tests were carried out according to ASTM E10-07 standards using Brinell hardness testing machine with a 10 mm ball indenter and 500 kg load for 30 s. The test was conducted at room temperature (30^0C) and the measurement of hardness was taken at three different places on each sample to obtain an average value of hardness. As per the ASTM E08-8 standard, the tensile strength was evaluated on the cylindrical rod of casted composites. The 1200 grit grindings silicon carbide paper was used to polish the test specimens in order to decrease the machining scratches and the effects of surface defects on the sample. The universal testing machine was loaded with 10 KN, load cell was used to conduct the tensile test. The affecting factors and levels selected for mechanical behaviour Al5086/Gr/Al_2O_3 are given in Table 2.

TABLE II
Affecting factors and levels selected for tensile strength Al5086/Gr/Al_2O_3

Factors /levels	1	2	3
X- wt. % Al_2O_3 (wt. %)	4	8	12
Y- wt. % Graphite (wt. %)	2	4	6

C. *Tribological behaviour*

The pin on disc test apparatus is used to investigate the dry sliding wear behaviour of Al5086/12 wt. % Al_2O_3/ Gr hybrid composites. Pin specimens of 6 mm diameter and 15 mm height for wear test was prepared from the above composites were machined and polished. The test was conducted with various loads of 15 N, 30 N and 45 N at a sliding speed of 125, 2.50, 3.25 m/s and 2, 4, 6 Gr wt. %. The test was conducted at room temperature (30^0C) and relative humidity of 60–65%. The affecting factors and levels selected for Tribology Al5086/12 wt. % Al_2O_3/ Gr is given in Table 3.

Table III
Affecting factors and levels selected for Tribology Al5086/12 wt. % Al_2O_3/ Gr

Factors /levels	1	2	3
A-Load (N)	15	30	45
B-Sliding velocity (m/s)	1.25	2.50	3.25
C-wt. % of Gr (wt. %)	2	4	6

III. RESULT AND DISCUSSION

A. *Optimum setting for TS & BHN of Al5086/Al_2O_3/ Gr*

The tensile strength and hardness of the Al5086/4, 8, 12 wt. % Al_2O_3/2, 4 wt. % Gr hybrid composites is shown in Figure 1(a) and Figure 1 (b). It is observed that an addition of alumina particles improve the tensile strength and hardness of hybrid composites. It is evident that tensile strength and hardness clearly increases with the addition of alumina particles. The tensile strength and hardness of the Al5086/4, 8, 12 wt. % Al_2O_3/6 wt. % Gr hybrid composites is shown in Figure 1(c). Increase in content of graphite the tensile strength and hardness of hybrid composite is decreased.

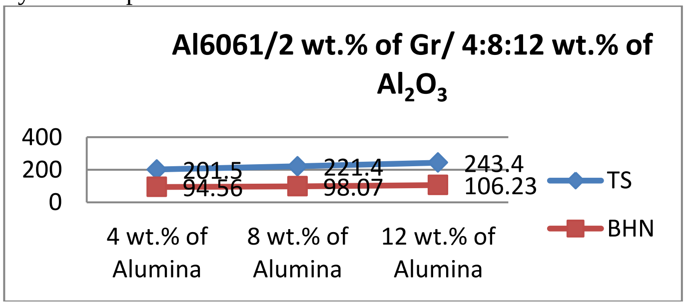

Fig. 1 (a) Mechanical behaviour of Al5086/2 wt. % of Gr/4:8:12 wt. % of Al_2O_3

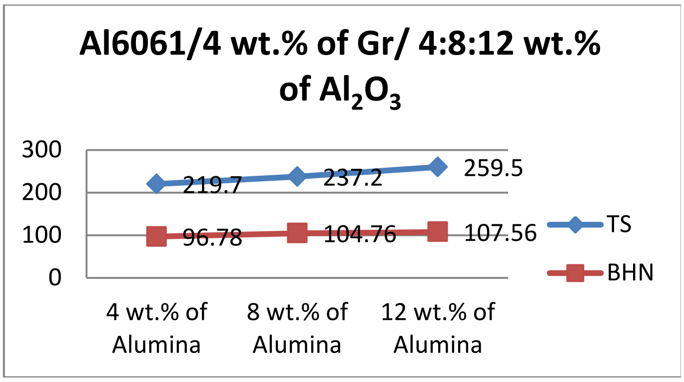

Fig. 1 (b) Mechanical behaviour of Al5086/4 wt. % of Gr/ 4:8:12 wt. % of Al_2O_3

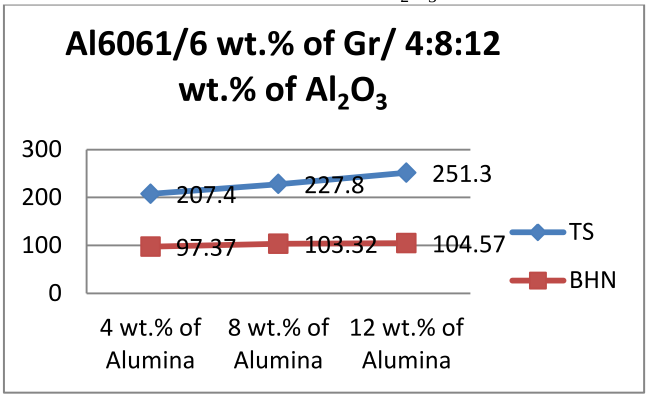

Fig. 1 (c) Mechanical behaviour of Al5086/6 wt. % of Gr/ 4:8:12 wt. % of Al_2O_3

TABLE V

Experimental result for tensile strength of Al5086/Al_2O_3/ Gr

X	Y	Al_2O_3 (wt. %)	MoS_2 (wt. %)	TS (N/mm^2)	S/N Ratio	BHN	S/N Ratio
1	1	4	2	201.5	46.0855	94.56	33.2713
1	2	4	4	219.7	46.8366	96.78	33.4117
1	3	4	6	207.4	46.3362	97.37	33.3184
2	1	8	2	221.4	46.9036	98.67	33.4241
2	2	8	4	237.2	47.5023	104.76	33.5343
2	3	8	6	227.8	47.1511	103.32	33.4698
3	1	12	2	243.4	47.7264	106.23	33.5752
3	2	12	4	259.5	48.2827	107.56	33.6758
3	3	12	6	251.3	48.0038	104.57	33.6255

TABLE VI

Taguchi Analysis: TS & BHN versus X, Y of Al5086/Al_2O_3/ Gr

Level	TS		BHN	
	X	Y	X	Y
1	46.42	**46.91**	33.33	33.42
2	47.19	47.54	33.48	**33.54**
3	**48.00**	47.16	**33.63**	33.47
Delta	1.58	0.64	0.29	0.12
Rank	1	2	1	2

The measured values of tensile strength and BHN for Al5086/Al_2O_3/ Gr under different wt. % and corresponding signal to noise ratio for all experimental runs are given in Table 5. The Taguchi analysis of tensile strength and BHN for Al5086/Al_2O_3/Gr under different wt. % is given in Table 6. It clearly shows the maximum tensile strength is obtained at 12 wt. % of Al_2O_3 and 2 wt. % of Gr and the maximum BHN is obtained at 12 wt. % of Al_2O_3 and 4 wt. % of Gr. Table 7 shows that the results of ANOVA for tensile strength and BHN on Al5086/Al_2O_3/ Gr hybrid composite. It is observed that Al_2O_3 is the most significant parameter affected the tensile strength of Al5086/Al_2O_3/ Gr with F: P value of 1092.26: 0.000 and Al_2O_3 is significantly affecting the BHN of Al5086/Al_2O_3/ Gr with F: P value of 480.69: 0.000.

B. Tribological behaviour of Al5086/Al_2O_3/ Gr

The variation of wear rate for Al5086/Al_2O_3/ Gr hybrid composite with respect to different sliding velocity and applied load is given in Table 8. The applied load affects the wear rate of hybrid composites significantly. The wear rate varies with applied load is an indicative of Archard's law and significantly lower in the case of hybrid composites. The wear rate increases with increasing applied load and it is less at 6 wt. % of Gr hybrid composites as compared to 2 wt. % of Gr . This is mainly due to the presence of Al_2O_3 in Al5086. However, at all load conditions are considered the wear resistance of the hybrid composites were superior to the matrix alloy. The wear rate is increased with increase in sliding speed Al5086/12 wt. % Al_2O_3/ Gr hybrid composite. Increasing sliding speed temperature is raised to the sliding surfaces this leads to softening of the matrix and composite pin surfaces and it is due to the enhancement in the hardness. The increase in hybrid composite hardness results in improvement of wear resistance. The presence of Gr and Al_2O_3 particles in the hybrid composite will lead to further reduction of wear rate. The coefficient of friction for Al061/12 wt. % Al_2O_3/ MoS_2 hybrid composites under varying load and sliding velocity is given in Table 8. The coefficient of friction is decreased with increasing wt. % of Graphite and increasing the due to load. The Al_2O_3 particles act as load bearing elements in the hybrid composites and also it results in formation of more stable lubricating film on the Tribo surface of the hybrid composites. The decreased coefficient of friction of hybrid composite with Graphite content can be credited to the

collective effects of Graphite and Al_2O_3 particles in formation of a more resistant Tribo layer on the contact surface. The graphite Tribo film minimize the degree of shear stress transferred to the sliding material underneath the sliding contact area which results in less plastic deformation in the sub surface region and reduces the wear rate in the hybrid composites. The experimental values of wear rate and coefficient of friction for Al5086/12 wt. % Al_2O_3/ Graphite under different parameters and corresponding signal to noise ratio for all experimental runs are given in Table 8. The Taguchi analysis for Al5086/12 wt. % Al_2O_3/ Graphite under different load, sliding velocity and wt. % of Graphite is given in Table 9. It clearly shows the minimum wear rate and coefficient of friction is obtained at 15N of load, 3.25 m/sec of sliding velocity and 6 wt. % of Graphite. Table 10 shows that the results of ANOVA for wear rate and coefficient of friction on Al5086/12 wt. % Al_2O_3/ Graphite hybrid composite. It is observed that load is the most significant parameter affecting the wear rate and coefficient of friction of Al5086/12 wt. % Al_2O_3/ Graphite with F: P value of 29.06: 0.033 and 756.27:0.001.

TABLE VII

Analysis of Variance for TS & BHN of Al6061/Al_2O_3/ MoS_2

Source	DF	TS				BHN			
		Seq SS	Adj MS	F	P	Seq SS	Adj MS	F	P
X	2	2634.78	1317.39	1092.26	0.000	3.7691	1.8845	480.69	0.000
Y	2	423.56	211.78	175.59	0.000	0.6125	0.3063	78.12	0.001
Error	4	4.82	1.21			0.0157	0.0039		
Total	8	3063.17				4.3973			
R-Sq = 99.84%; R-Sq(adj) = 99.69%						R-Sq = 99.64% ; R-Sq(adj) = 99.29%			

TABLE VIII

Experimental results for Al6061/12 wt. % Al_2O_3/ Graphite of wear study

Trial	A	B	C	Load (N)	Sliding velocity (m/s)	wt. % of Gr (Wt. %)	Wear rate (mm^3/min) X 10^{-3}	S/N	Coefficient of friction	S/N
1	1	1	1	15	1.25	2	1.346	-2.580	0.487	6.249
2	1	2	2	15	2.50	4	1.250	-1.938	0.455	6.839
3	1	3	3	15	3.25	6	0.966	0.300	0.423	7.473
4	2	1	2	30	1.25	4	2.344	-7.399	0.523	5.629
5	2	2	3	30	2.50	6	2.576	-8.218	0.496	6.090
6	2	3	1	30	3.25	2	2.133	-6.579	0.537	5.400
7	3	1	3	45	1.25	6	2.756	-8.805	0.568	4.913
8	3	2	1	45	2.50	2	3.813	-11.625	0.603	4.393
9	3	3	2	45	3.25	4	3.245	-10.224	0.579	4.746

TABLE XI

Taguchi Analysis: Wear rate and coefficient of friction versus A, B, C of Al5086/12 wt. % Al_2O_3/ Graphite

Level	Wear rate			Coefficient of friction		
	A	B	C	A	B	C
1	**-1.406**	-6.262	-6.929	**6.854**	5.597	5.348
2	-7.399	-7.261	-6.521	5.707	5.775	5.739
3	-10.218	**-5.501**	**-5.575**	4.684	**5.873**	**6.159**
Delta	8.812	1.760	1.354	2.170	0.276	0.811
Rank	1	2	3	1	3	2

TABLE X

Analysis of Variance for Wear rate of Al5086/12 wt. % Al_2O_3/ Graphite

		Wear rate				Coefficient of friction			
Source	DF	Seq SS	Adj MS	F	P	Seq SS	Adj MS	F	P
A	2	6.5442	3.2721	**29.06**	**0.033**	0.0247047	0.0123523	**756.27**	**0.001**
B	2	0.3456	0.1728	1.53	0.395	0.0002580	0.0001290	7.90	0.112
C	2	0.1651	0.0826	0.73	0.577	0.0032667	0.0016333	100.00	0.010
Error	2	0.2252	0.1126			0.0000327	0.0000327		
Total	8	7.2801				0.0282620			
R-Sq = 96.91% R-Sq(adj) = 87.63%						R-Sq = 99.88% R-Sq(adj) = 99.54%			

IV. CONCLUSION

In the present investigation, the Al5086/Al_2O_3/ Graphite hybrid composite was successfully fabricated using stir casting process. The mechanical behaviour and tribological behaviour were evaluated. The obtained results can be summarized as follows:

- Mechanical properties of hybrid composites increase with an increase in weight fraction of alumina particles. An increase in weight fraction of molybdenum disulphide reinforcement decreases the mechanical properties like tensile strength and BHN. The optimum parameter for maximization of tensile strength is obtained at 12 wt. % of Al_2O_3 and 2 wt. % of Graphite and the maximum BHN is obtained at 12 wt. % of Al_2O_3 and 4 wt. % of Graphite
- The incorporation of Al_2O_3 reinforcement to Al5086 increases the wear resistance of the composites. The addition Graphite reinforcement in Al5086/Al_2O_3 composites as a hybrid reinforcement further increases the wear and friction resistance of the composite. This is attributed to the stable and Graphite rich mechanically mixed layer, which prevents metal to metal contact and reduces the wear of the composite. The unstable mechanically mixed layer in the absence of the lubricant phase leads to lower wear resistance in Al5086/Al_2O_3/ Graphite hybrid composite. The optimum parameter for minimization wear rate and coefficient of friction is obtained at 15N of load, 3.25 m/sec of sliding velocity and 6 wt. % of MoS_2.

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Biographies and Photographs

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